Casting polyurethane in silicone rubber molds

—June 27, 2006—

1 Choice of materials

As for materials, the following will be needed:

Polyurethane—For this, I used exclusively the two-component material *Biresin G27* (produced by *Sika*, `http://www.sika.de`) which shrinks little and is, compared to other products in the Biresin line, less aggressive on molds (especially *G26-new* is a killer on silicone rubber molds). The only feature some modelers may find troublesome is that once the two components are mixed (ratio 1:1 which is quite convenient), casting has to be completed in about 70 to 90 seconds. In turn therefor, one may remove the workpiece in the average already 30 minutes later.

Longer storage has certain unwanted effects on the components, such as the B-component turning into a crystalline mass after longer contact with air, making therefore the opening of rarely used packaging a real task, and the A-component accumulating a thick deposit on the bottom of the container. The latter has to be thoroughly homogenized again before use, otherwise the mixture easily tends to develop gas bubbles during hardening. Altogether, I could obtain excellent results even with raw material stored much longer than its specified maximum storage time, so modelers are encouraged to actually test the quality of the material before disposing of it.

Silicone rubber—I have most experience with the addition-hardening products of the Hungarian company *T-Silox* (`http://www.t-silox.hu`), but I have seen suitable equivalents everywhere. While I lived in Germany, I used the products of *Weissmetall Dicke & Co.* (`http://www.weissmetall.de`), among them a condensation-hardening type, which were comparable to the Hungarian equivalents (in some cases even better) in quality and handling. The actual choice of the silicone rubber depends on the following aspects:

- Neither the silicone rubber mass nor the hardener should attack the original you would like to make a copy of.
- The hardened material should be resistant against ripping and propagation of fissures. This is important because some details on the form to be cast can locally apply huge stress on the mold when the casting is removed.
- Flexibility vs. rigidity of the mold material must be adequate. If a mold is too flexible, the casting can be deformed, while a too rigid mold makes removal difficult and may not last long.
- The material of the mold should resist the polyurethane used for casting and it should not stick to it.
- The auxiliary materials used for making molds should not inhibit the hardening reaction. I have never experienced that any material used for casting would do this, but it is theoretically possible.

Silicone oil spray—Before pouring the silicone rubber mixture into the mold, I apply a thin layer of silicone oil on the positive original to be copied. This enhances the capillary effect and draws most silicone rubber materials to the surface of the original.

Talcum powder—Also, sufficiently fine powder of calcium carbonate or magnesium carbonate, or even cosmetic talcum powder will do. This is evenly distributed with a fine brush over the mold's surface before polyurethane casting, and the rest is shaken or blown out of the mold. The powder enhances the capillary effect and draws the liquid polyurethane mixture into all details of the mold, preventing air bubbles.

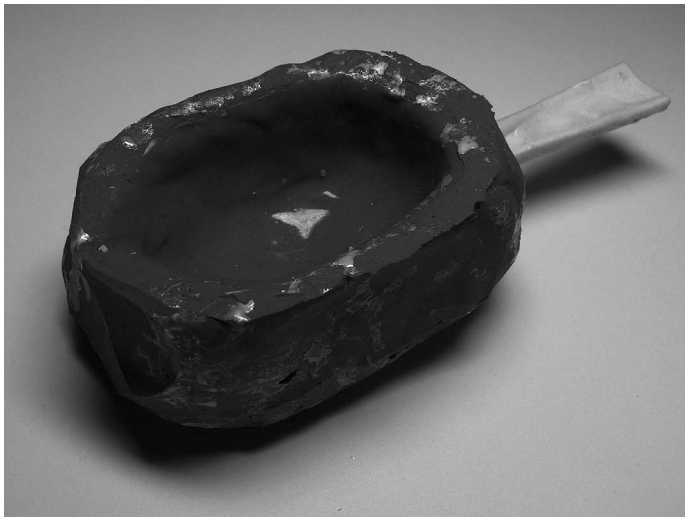

Figure 1: Home-made silicone rubber casting ladle

Hair lacquer spray—This is used as a release agent when two-part molds are made, to prevent the two halves of the mold sticking to each other.

Thick cardboard, thick polystyrene sheets etc.—Used to build a frame for the mold, not only applied during casting the silicone material but also during use of the mold itself if the mold is prone to deformation due to its large size. Also, a solid frame for the mold can be made out of wood, some modelers even rely on LEGO bricks.

Polypropylene sheets—Often used with one-part molds to give the casting a smooth rear surface. Should be transparent if possible to allow timely detection of air bubbles. The polyurethane mixture does not attack PP and does not stick to it, as opposed to polystyrene which especially the A component of *Biresin G27* can slightly attack. In some cases, it may become difficult to peel the polyurethane casting from the ploypropylene backplane without deformation. In this case, the thick PP sheet may be replaced with a PP foil (such as a piece of a PP document pocket) plus a supporting surface (such as a thick PS sheet or cardboard).

Modeling clay—Used especially for creating two-part molds, for "stuffing" the hollows inside the original workpiece etc. Before venturing to cast a real mold, one should always test whether the oily medium of the modeling clay interacts with the silicone rubber mass.

Adhesive tape—Used to secure the rim of the cardboard/PS mold frame to the base plate. Also, the inner surface of cardboard or paper inlays can be covered with tape to facilitate the removal of hardened silicone rubber and polyurethane.

Thick water-based glue—Used to secure the surrounding frame of the silicone rubber mold to the base surface when the mold itself is made. Also, smaller gaps can be filled with it in a hollow workpiece to be copied. My personal choice is bookbinding glue which, due to its water-based composition, will not attack plastics and can be easily removed from most plastic surfaces after hardening.

2 Tools

Making molds and casting requires no big assortment of special tools other than those used by modelers anyway. One should have some spoons, ladles or some smaller vessels at hand for measuring the amount of material needed, a pair of rubber gloves, a roll of paper towels for cleaning off material remnants, toothpicks for precise dosage of hardener, and a clean glass or stainless steel rod for stirring the urethane and silicone materials before use. The only special tool is a casting ladle (Fig. 1) which should be made of a material polyurethane does not stick to. I made a casting ladle myself out of silicone rubber and keep using this one ever since I started casting polyurethane more than six years ago.

3 Planning

3.1 One-part mold or two-part mold?

The geometry of some parts to be cast apparently answers this question immediately, as a one-part mold with a polypropylene backplane is the best choice for pieces ending in a flat surface, such as truck side frames (see Fig. 2), while small but complicated pieces, such as horns, buffers etc., already need a two-part mold.

As for complete shells, one can choose two basic technologies (see Fig. 3). Using a one-part mold, one tries to distribute the urethane casting material evenly in the mold (applying further layers if needed) and fits the irregular inner surface later to the frame of the model. Some people even use a strengthening tissue when a second layer is applied; this may be advantageous for larger scales. Two-part molds, on the other hand, require only one casting step and give a definite inner surface, though here, the risk of including air bubbles is much higher. Two-part molds are often used in smaller scales (such as the N scale example in this description).

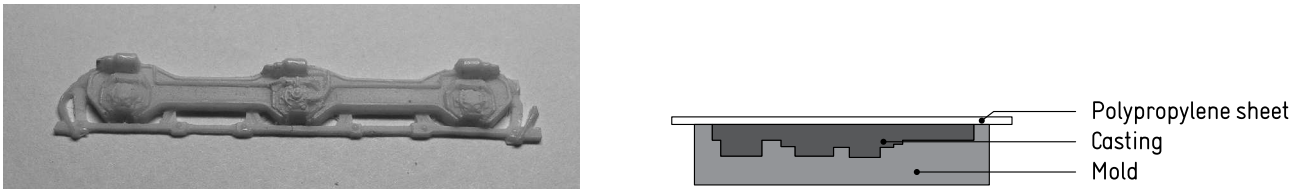

Figure 2: Truck side frame and suggested casting method

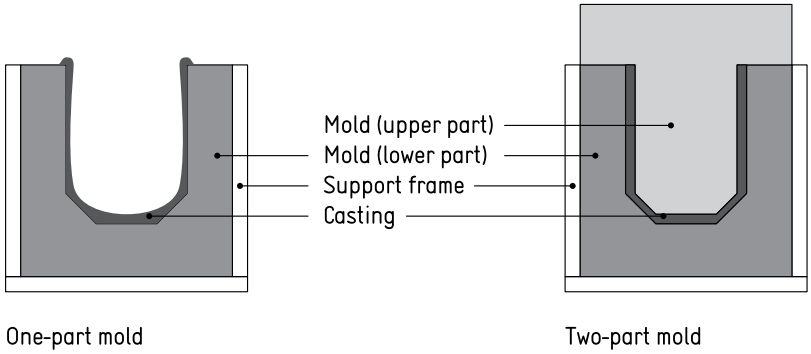

Figure 3: Different technologies used in body shell casting

3.2 Decomposition into several pieces

This is recommended in two cases. First, it may be necessary to cast the shell in several pieces and assemble it afterwards if there are large undercuts (see Fig. 4) that would make a one-piece casting exceedingly difficult (though smaller undercuts, such as snap-on pits, are quite well tolerated by silicone rubber molds).

Also, some fine details of the model may be worth casting as separate pieces (see Fig. 5). This has two reasons. First, it may be difficult to cast these details free of air bubbles if they are a part of a larger mold. Second, fine details are the most vulnerable parts of the mold and usually, they become destroyed much earlier during repeated casting than large smooth surfaces. Therefore, using separate small molds for the detail pieces may save the modeler from rebuilding a worn-out mold too often.

3.3 Dimensions of the mold

The mold surrounding the workpiece should be thick enough to withstand unwanted deformation during casting. On the other hand, it may become too difficult to remove the hardened workpiece if the mold is too massive

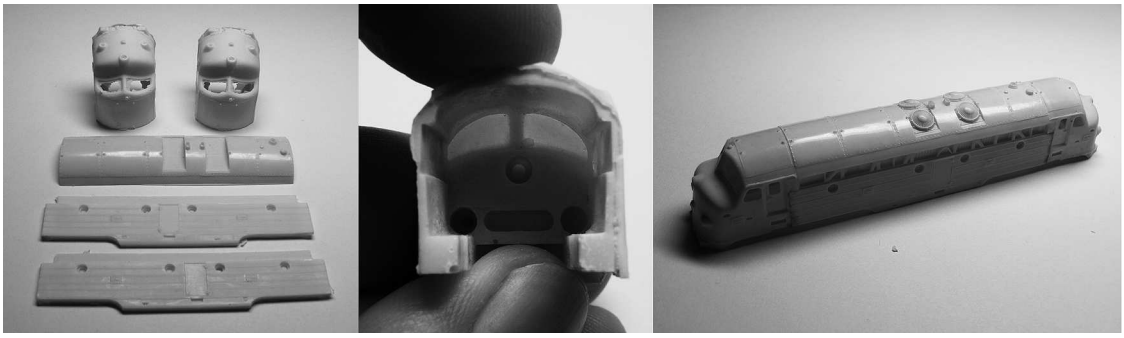

Figure 4: Decomposition due to large undercuts (shown in the middle), and assembled shell

Figure 5: Decomposition of fine details

and rigid. Therefore, a compromise should be worked out which, of course, depends much on the material used. Experience with N scale shells let me conclude that as a rule of thumb, an average mold thickness of 1–2 centimeters should be enough for two-part molds of complete shells while molds for smaller parts can be much thinner.

3.4 Geometry

It is important to thoroughly plan the placement of the workpiece within the mold. Two important aspects must be taken into account. First, the mold must be constructed so that the formation of air bubbles during casting is as much prevented as possible. If needed, additional channels must be included into the mold where bubbles and excess casting material can leave. Second, the hardened workpiece should be removable without risking damage to the mold and the casting itself.

4 Making the mold

Here, I will describe the process of making a two-part mold for a complete (N scale) shell, since all other cases need a subset of these technological steps.

4.1 Preparing the original positive

1. First, a sufficiently large flat surface (such as a thick polystyrene sheet) will be needed.
2. Form a small mound of modeling clay whose size is determined by the dimensions of the original shell. If needed, negatives of channels for escaping air and excess polyurethane should be formed as small strips on the surface of the mound. These can be applied after placing the shell on the base as well.

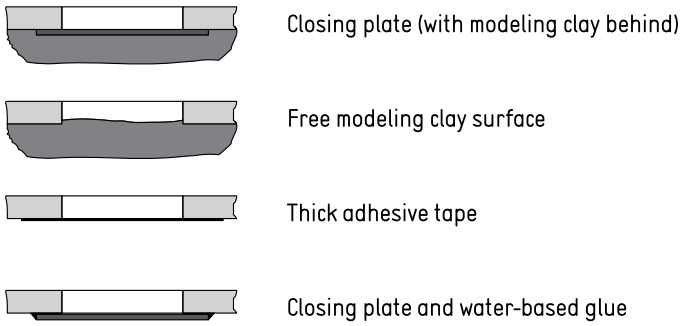

Figure 6: Various ways of covering apertures on the original shell

3. The shell should be either stuffed with modeling clay, or all apertures on it (such as windows, portholes etc.) must be covered by adhesive tape, thick paper etc. (see Fig. 6). Make sure that all holes are sufficiently stopped and cannot be easily pushed in by the silicone rubber mass. Also, it may be feasible to use thick water- soluble glue (I use bookbinding glue on less sensitive pieces where preserving original livery is not a concern).

4. Place the shell on top of the mound. The shell should be seated firmly on the base, without gaps exposing the inside of the shell, and without modeling clay overlapping with the outside of the shell (in other words, the separation line should be somewhere on the lower edge of the shell where it least disturbs the appearance of the casting to be made).

5. Assemble a frame for an outer rim of the mold. This can be made of any material which can be released from the silicone rubber used for the mold, and should be stiff enough to withstand deformation due to the weight of the silicone rubber mass. I usually use layers of thick cardboard or thick polystyrene for this purpose but there is a wide range of other materials one can rely on. Make sure that both the top and the bottom of the frame are sufficiently level.

6. Put the frame onto the base surface so that space around the mound with the shell is distributed evenly and attach it with glue. If you use polystyrene for a base surface, it is best to use some kind of water-based glue which does not attack polystyrene, so that the base plate remains reusable. Allow the glue to dry, then check for possible leaks. These should be stopped either with the same glue, or adhesive tape or small amounts of modeling clay. Also, strips of adhesive tape can be additionally used to fasten the frame to the base plate but this is not needed too often.

7. Apply a thin layer of silicone oil onto the shell. It is not necessary to treat the rest of the surfaces as silicone oil is only used to help the capillary forces to draw the silicone rubber mass into the finer details of the shell. Should the silicone spray contain solvent (before applying, check if it attacks the original shell), allow it to evaporate properly. Also, the silicone oil film may be grainy right after spraying, so you have to wait anyway until it settles evenly on the shell. For this time, it may be advantageous to cover the prepared mold with a light tissue or a paper towel to keep off dust.

Having completed the above steps, the prepared arrangement should look like in Fig. 7

4.2 Casting the lower half of the mold

1. Mix a proper amount of silicone rubber mass plus hardener. Some silicone products, usually the addition-hardening kind, need very thorough mixing, so gather some experience before you make the first mold that really counts. A common fault is a leftover layer of unmixed silicone rubber mass sticking to the wall of the mixing vessel—this should be avoided as it may add threads to the mold that never harden. Also, as much air bubbles must be removed from the mixture as possible. Though the most professional solution would be a vacuum chamber, my own experience says that this is, at least in N scale, not necessary and hitting the mixing pot against the table a couple of times may suffice.

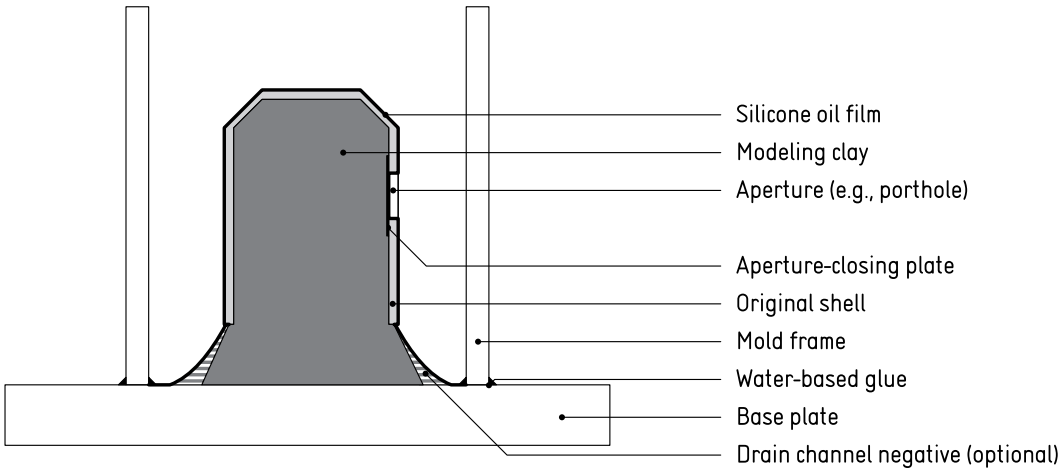

Figure 7: Arrangement to cast the lower half of the mold

2. Depending on the consistency of the silicone rubber mass, it may be necessary to force a small amount of the mass manually into the details of the shell, while others seep into all gaps without any help if the mass is poured into the mold slowly enough. Make some tests first with the material of your choice to see how it behaves. Having covered the finer details if needed, begin pouring the silicone rubber mass slowly into the mold, leaving enough time to constantly inspect that no air bubbles are trapped. This technique is facilitated by the fact that silicone rubber mass usually behaves like a viscous honey-like fluid that can be dosed very exactly.

3. Pour enough silicone rubber into the mold to make a completely flat upper surface (as this will be the bottom of the mold when used for casting). Sometimes, it is even recommended to place a sheet of polypropylene over the silicone rubber mass. If the mold material is thick enough, air bubbles accumulating below this closing surface mean no problem as the lower parts of the mold are by then usually free of floating bubbles.

4. Allow the material to set for a sufficient amount of time. To avoid removing the mold too early, I always let it untouched for at least 24 hours.

5. Now, carefully remove the mold and pull the shell out of it.

6. At this point, additional drain channels can be cut into the mold if they were not prepared previously during preparation of the modeling clay base. This should be, however, avoided if the silicone rubber material used is not very resistant against fissure propagation. (Make some tests with dummy blocks of silicone material if needed.)

7. Once the rubber mold is removed and de-burred if needed, it should be cleaned of any remnant of modeling clay etc. It is best to carefully clean it in hot water with a neutral detergent and then let it dry on a warm and dust-free place.

8. Carefully put the shell back into the mold and fill the drain channels, if any were worked into the mold, with strips of modeling clay.

9. Apply a thin layer of talcum powder onto free silicone rubber surfaces which will contact with the other part of the mold. This talcum layer will allow an even distribution of the hair spray or other release agent (see later) which would otherwise gather to beads instead of evenly dispersing over the entire surface.

4.3 Casting the upper half of the mold

1. Assemble a frame of cardboard, polystyrene etc. which has exactly the same dimensions as the one used for the lower half, except for being somewhat higher. The additional height is determined by the size of the mold itself; for an average N scale shell, 1.5–2 centimeters are a reasonable choice.

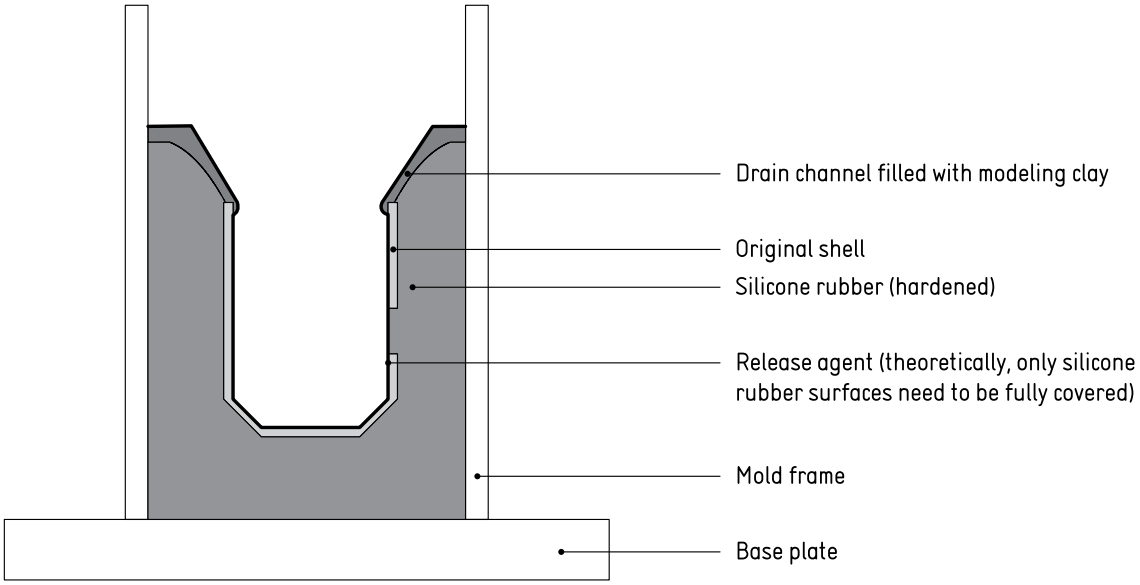

Figure 8: Preparations to cast the upper half of the mold

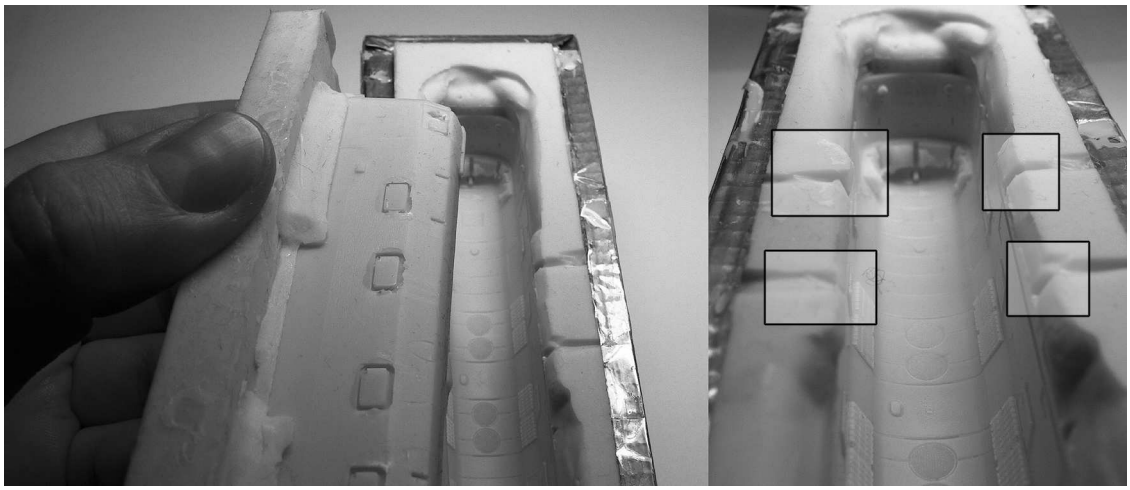

Figure 9: Two halves of the mold—the highlighted areas show the draining channels cut into the mold after casting the silicone rubber pieces

2. Put the prepared lower half of the mold into the frame and make sure it is free of any notable physical stress as this would result in the two halves of the mold not fitting properly in use.

3. Apply a sufficiently thick layer of hair spray on the free rubber surfaces and let the solvent evaporate (Fig. 8). After this step, do not move or apply force to the rubber casting as the release agent layer may be rigid and could crack or peel off.

4. Spray a thin layer of silicone oil onto the surface if needed. Usually, the upper half of the shell is not that much of interest as far as surface quality concerns, so that this step can be left out if the solvent of the silicone oil spray seems to attack the release agent layer.

5. Pour a sufficient amount of silicone rubber mass into the prepared mold and let it set for a proper amount of time, just as in the case of the lower half of the mold.

6. After hardening is complete, remove the upper half of the mold, then remove the shell itself, finally de-burr and clean the two halves as described before. Now your two-part mold is ready for use.

5 Casting the workpiece

Attention: many casting materials, including the *Biresin* line of products, require proper ventilation if larger amounts are used, mostly due to the cyanide derivatives contained in the raw material.

5.1 Preparing the mold

1. Apply a thin layer of talcum powder onto the two halves of the mold, for example, with a small but firm brush. Shake or blow away excess powder.

2. Put the lower half of the mold into the frame used to cast the lower half (Fig. 7). This will prevent deformation of the mold.

5.2 Casting the polyurethane mass

1. Mix a small amount of urethane material and, using a small screwdriver or toothpick, apply small droplets to places of the mold where fine details are. Usually, the capillarity of the talcum powder draws the urethane fluid right into the gaps without leaving air bubbles. Should air bubbles remain, they can be removed with the same screwdriver or toothpick. Be careful not to damage the mold when removing bubbles. (For smaller detail pieces cast separately, it is not necessary to mix two doses of urethane as possible air bubbles can be conveniently removed even with the entire mold being filled with the casting material.)

2. Mix a larger amount of urethane material and pour it into the lower half of the mold, slowly enough to keep off air bubbles.

3. Put the upper half of the mold carefully in place, always watching out for possible air bubbles trapped, though most of these should leave together with excess casting material through the drain channels. Do not press the upper half too firmly yet; in the ideal case, the two halves should still be a few millimeters apart, but the gap between them should be already filled completely with the urethane casting material.

4. Now, place a thick sheet of plastic or a piece of cardboard on top of the mold and put some weight on it, so that the upper half remains depressed but no notable deformation occurs (see Fig. 10). Leave it this way for the amount of time the urethane mass needs to harden. Note that even after the setting time is over, the casting remains somewhat plastic for a while and could be permanently deformed if removed from the mold too early. It is better to wait for longer than ending up with a damaged casting. The rigidity of the casting can be estimated if, for example, the remaining polyurethane mixture is poured onto a flat surface for sampling.

5. If the casting is rigid enough, the frame surrounding the mold can be removed. Usually, it is safest to remove the upper half next, and then, the casting is taken out of the lower half. Now, the copy of the shell is ready for post-processing, such as de-burring and correction of smaller flaws etc. Should a larger air bubble be trapped, carefully open it from the inside of the mold, let some urethane mixture creep into it and let it harden. For flaws that show on the outside, it is often better to use epoxy putty. For adding further details or separately cast parts, superglue (preferably of a gel-like consistency) is best, at least, in the case of *Biresin*.

6. To prepare the mold for the next casting, it may be necessary to remove polyurethane remnants from the mold. Usually, a thin film separating the two halves of the mold remains. This is best removed with a broad adhesive tape. Hereafter, the mold can be again treated with talcum powder and prepared for the next casting procedure. If many castings are made, a thorough cleaning of the mold after every 5–10 casting steps may be recommended, but this is largely determined by experience with the actual mold.

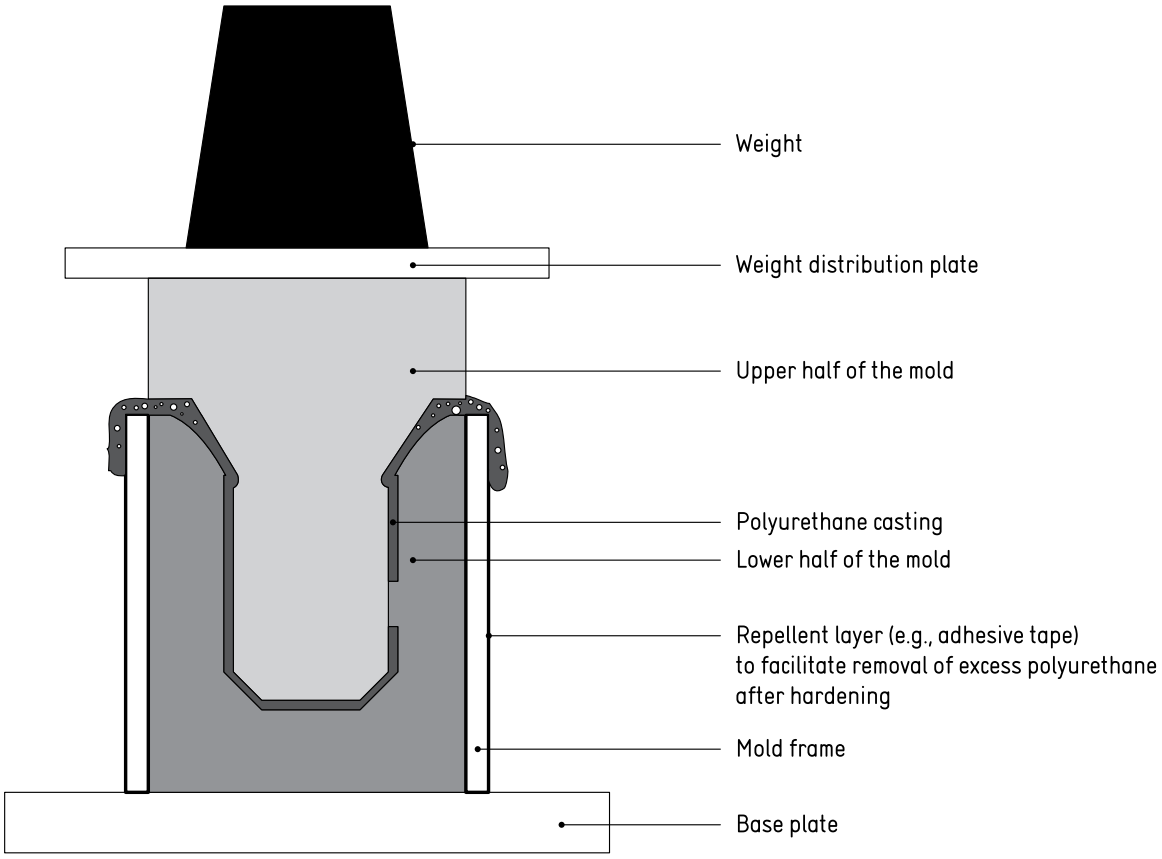

Figure 10: Casting the workpiece

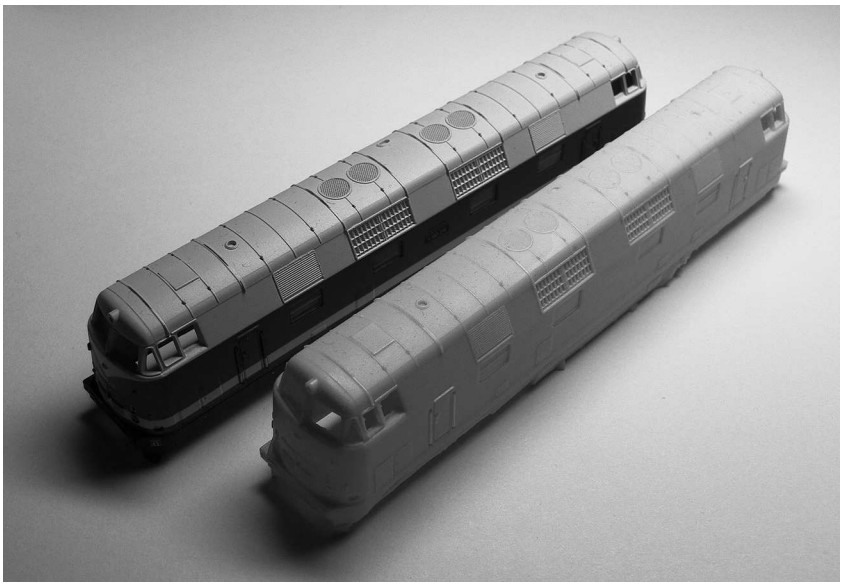

Figure 11: Original shell and polyurethane copy made with the mold of Fig. 9